JC05 Rec'd PCT/PTO 01 APR 2002

FORM PTO-1390 (REV. 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**	ATTORNEY'S DOCKET NUMBER 10191/2287 U.S. APPLICATION NO. (If known, see 37 CFR 1 5) 10/089621

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE(S) CLAIMED
PCT/DE00/03547	(09.10.00) 09 October 2000	(09.10.99) 09 October 1999

TITLE OF INVENTION
INTERFEROMETRIC MEASURING DEVICE FOR MEASURING SHAPE

APPLICANT(S) FOR DO/EO/US
LINDNER, Michael and DRABAREK, Pawel

Applicant(s) herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unsigned).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ A substitute specification and a marked up version thereof.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report, International Preliminary Examination Report and Form PCT/RO/101.

Express Mail No. EL327553862US

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U.S. APPLICATION NO. (if known, see 37 C.F.R.1.5) 10/089621	INTERNATIONAL APPLICATION NO PCT/DE00/03547	ATTORNEY'S DOCKET NUMBER 10191/2287

17. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO .... $890.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) ... $710.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .... $740.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $1,040.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	8 - 20 =	0	X $18.00	$ 0	
Independent Claims	1 - 3 =	0	X $84.00	$ 0	
Multiple dependent claim(s) (if applicable)			+ $280.00	$ 0	

TOTAL OF ABOVE CALCULATIONS =	$ 890	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).	$	
SUBTOTAL =	$ 890	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$ 890	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +	$	
TOTAL FEES ENCLOSED =	$ 890	
	Amount to be: refunded	$
	charged	$

a. ☐ A check in the amount of $________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of $890.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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(Reg. No. 36,177)

01 April 2002
DATE

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[10191/2287]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s)	:	Michael LINDNER et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	INTERFEROMETRIC MEASURING DEVICE FOR MEASURING SHAPE
Art Unit	:	To Be Assigned
Examiner	:	To Be Assigned

Assistant Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT AND
37 C.F.R. § 1.125 SUBSTITUTE SPECIFICATION STATEMENT

S I R:

Please amend the above-identified application before examination, as set forth below.

IN THE SPECIFICATION AND ABSTRACT:

In accordance with 37 C.F.R. § 1.121(b)(3), a Substitute Specification (including the Abstract, but without claims) accompanies this response. It is respectfully requested that the Substitute Specification (including Abstract) be entered to replace the Specification of record.

IN THE CLAIMS:

On the first page of the claims, first line, change "What is claimed is:" to --WHAT IS CLAIMED IS:--.

Please cancel, without prejudice, claims 1 to 8 in the underlying PCT application.

Please add the following new claims:

--9. (New) An interferometric measuring device for measuring shape, including surfaces of a measured object, comprising:

a radiation-producing unit emitting short-coherent radiation;

a beam splitter for forming a first beam component and a second beam component, wherein the first beam component is directed via an object light path to the measured object and the second beam component is directed via a reference light path to a reflecting reference plane;

a superposition element at which a radiation coming from the measured object and a radiation coming from the reflecting reference plane are brought to superposition;

an image converter which receives the superposed radiation and sends corresponding signals to a device for evaluation, wherein, for the measurement, an optical path length of the object light path is changed relative to an optical path length of the reference light path; and

an optical probe including an optical device for generating at least one optical intermediate image, wherein the optical probe is provided in the object light path.

10. (New) The measuring device according to claim 9, wherein the at least one intermediate image is generated in the object light path.

11. (New) The measuring device according to claim 10, wherein both the radiation directed to the measured object and the radiation returning from the measured object pass through the optical probe.

12. (New) The measuring device according to claim 9, further comprising, in the reference light path, one of a further optical probe and a glass device for compensating for a glass proportion present in the optical probe with regard to the elements for the intermediate image.

13. (New) The measuring device according to claim 9,

wherein the first beam component formed by the beam splitter is first directed via a first arm to a fixed first mirror;

wherein the second beam component is directed via a second arm to the reflecting element;

wherein the optical path difference between the first and the second arm is greater than a coherence length of the radiation;

wherein the radiations coming from the first mirror and the reflecting element are guided through a common optical probe using a further beam splitter;

wherein in the optical probe, a reference mirror is arranged at a distance from the measured object such that the path difference between the first mirror and the reflecting element is canceled; and

wherein one part of the radiation incident on the reference mirror is reflected to a photodetector device and another part is allowed to pass through to the measured object and is reflected from there to the photodetector device.

14. (New) The measuring device according to claim 13, wherein the reference mirror is provided on one of a flat face-plate and a prism.

15. (New) The measuring device as recited in claim 14, further comprising a fiber optic element positioned between the beam splitter and the further beam splitter.

16. (New) The measuring device according to claim 9,

wherein the radiation emitted by the radiation-producing unit is coupled into a fiber-optic element and is subsequently split by the beam splitter into the first and the second beam component;

wherein the first beam component is coupled out of the fiber-optic in one object arm and coupled into the optical probe via a further beam splitter, and is guided to the measured object, from which the radiation is guided via an optical arrangement to a photodetector device; and

wherein the second beam component in one reference arm is coupled out of the fiber-optic of the reference arm, passes through the further optical probe, is guided via a further fiber-optic element to the further beam splitter, and from there to the image converter for superposing with the radiation coming from the measured object.--.

REMARKS

This Preliminary Amendment cancels without prejudice original claims 1 to 8 in the underlying PCT Application No. PCT/DE00/03547 and adds without prejudice new claims 9 to 16 . The new claims, *inter alia*, conform the claims to U.S. Patent and Trademark

Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE00/03547 includes an International Search Report, dated February 21, 2001. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,
KENYON & KENYON

Dated: 4/1/02

By: for Richard Mayer (by Jay Lee Reg. No. 36,197)
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[10191/2287]

INTERFEROMETRIC MEASURING DEVICE FOR MEASURING SHAPE

FIELD OF THE INVENTION

The present invention relates to an interferometric measuring device for measuring the shape especially of rough surfaces of a measured object, having a radiation-producing unit emitting short-coherent radiation, a beam splitter for forming a first and a second beam component, of which the first is directed via an object light path to the measured object and the second is directed via a reference light path to a reflective reference plane, having a superposition element at which the radiation coming from the measured object and the reference plane are brought to superposition, and an image converter which receives the superposed radiation and sends corresponding signals to a device for evaluation, the optical path length of the object light path being changed relative to the optical path length of the reference light path.

BACKGROUND INFORMATION

Interferometric measuring devices are known from German published patent document No. 197 21 842. In the case of this conventional measuring device, a radiation-producing unit, such as a light-emitting diode or a superluminescent diode, emits a short-coherent radiation, which is split via a beam splitter into a first beam component guided over an object light path, and a second beam component guided over a reference light path. The reference light path is periodically changed, using two deflector elements and a stationary diffraction grating positioned behind it, by activating the deflector elements, so as to scan the object surface in the depth direction. If the object light path and the reference

light path coincide, a maximum interference contrast results, which is detected using an evaluation device post-connected to the photodetector device.

An interferometric measuring device representative of the measuring principle (white-light interferometry or short-coherent interferometry) is also specified in German published patent document No. 41 08 944. Here, however, a moved mirror is used to change the light path in the reference ray path. In this method, the surface of the object is imaged on the photodetector device, using an optical system, it being difficult, however, to conduct measurements in cavities.

Additional such interferometric measuring devices and interferometric measuring methods based on white-light interferometry are described by P. de Groot, L. Deck, "Surface Profiling by Analysis of white-Light Interferograms in the Spatial Frequency Domain" J. Mod. Opt., Vol. 42, No. 2, 389-401, 1995 and No. T. Maack, G. Notni, W. Schreiber, W.-D. Prenzel, "Endoskopisches 3-D-Formmesssystem",(Endoscopic 3-D Shape Measuring System) in Jahrbuch für Optik und Feinmechanik, Ed. W.-D. Prenzel, Verlag (publisher) Schiele und Schoen, Berlin, 231-240, 1998 (submitted).

In the case of the interferometric measuring devices and measuring methods named, one difficulty is making measurements in deep cavities or narrow ducts. One suggestion for a measuring device in which measurements may be performed even in cavities, using white-light interferometry, is described in German published patent document No. 197 21 843. It is described there to split a first beam component further into a reference beam component and at least one measuring beam component, an additional beam splitter and the reference mirror being positioned in a common measuring probe. To be sure, such a measuring probe may be introduced into cavities, however, using this device, in each measurement, only a small, dot-like location in the surface may be scanned. In order to

take the measure of more locations on the surface in the depth direction, relative motion between measured object and measuring probe is required, an exact lateral coordination, however, being costly and difficult.

SUMMARY

The object of the present invention is to make available an interferometric measuring device, of the kind mentioned at the outset, which especially makes possible simplified measurements in deep cavities with great accuracy.

According to the present invention it is provided that an optical probe in the object light path, having an optical device for generating at least one optical intermediate image, be provided.

Similarly to an endoscope or a borescope, in using the optical device, because of the intermediate images, it becomes possible to image the observed surface, besides using high longitudinal resolution, also at high lateral resolution over a path which may be long compared to the diameter of the imaging optics. For example, the optical probe may be introduced into the bores of valve seats or into vessels of organisms for the purpose of medical measurements. In contrast to the usual endoscope, quantitative depth information may be now obtained. In this connection, an example embodiment may be one in which the at least one intermediate image is generated in the object light path. For this, the same optical device may be used for illuminating the measured location on the measured object as for transmitting the radiation coming from the measured object to the photodetector device, if it is provided that both the radiation going to the measured object and the radiation coming back from it pass through the optical probe.

The optical image on the photodetector device may be improved by providing, in the reference light path, an equal, further

optical probe or at least a glass device for compensating for a glass proportion present in the optical probe with regard to the elements for the intermediate image(s).

A favorable construction, as far as handling is concerned, may be one in which the optical motion difference between the first and the second arm is greater than the coherence length of the radiation; the radiation coming from the first mirror and the reflecting element may be guided through a common optical probe (common path) using a further radiation portion; in the optical probe, a reference mirror is arranged at such a distance from the measured object that the motion difference between the first mirror and the reflecting element is canceled, and one part of the radiation incident on the reference mirror is reflected to the photodetector device and one part is allowed to pass through to the measured object and is reflected from there to the photodetector device. A further benefit of this design may be that the object and reference waves pass through virtually the identical optics assembly, so that aberrations may be substantially compensated for. Moreover, this set-up may be more resistant to mechanical shocks. In this connection, two example embodiment possibilities may be, for the reference mirror, provided on a flat face-plate or on a prism.

In this connection, handling may further be simplified by arranging a fiber optic element between the beam splitter and the further beam splitter.

In this design too, splitting essentially into a probe part and a part having a modulation arrangement may be realized, handling being also favored.

The present invention is described in the following on the basis of example embodiments, with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates an example embodiment of an interferometric measuring device having an optical probe in a measured light path.

Figure 2 illustrates an example embodiment in which an optical probe is provided both in the measured light path and in the reference light path.

Figure 3 illustrates an embodiment of the interferometric measuring device having a common reference and measured light path.

Figure 4 illustrates an example embodiment in which, compared to Figure 3, fiber optics are provided between the first and a further beam splitter.

Figure 5 illustrates a further example embodiment of the interferometric measuring device.

DETAILED DESCRIPTION

Figure 1 illustrates an interferometric measuring device having a radiation-producing unit SLD emitting short-coherent radiation, as, for example a light-emitting diode or a superluminescent diode, whose radiation may be split by a beam splitter ST1 into a first beam component T1 of a measured light path and a second beam component T2 of a reference light path. The design may be like that of a Michelson interferometer. In the reference light path, the second beam component may be reflected by a reference plane in the form of a reference mirror RSP, the reference light path being periodically changed by moving the reference mirror RSP or by acoustooptical deflectors, as described in German published patent document No. 197 21 842, mentioned at the outset. If the change of the light path may be performed using two acoustooptical deflectors, a mechanically moved reflecting element becomes unnecessary, but instead, a fixed element,

e.g., a diffraction grating, may be used. By using a glass block G, the dispersion of an optical probe OSO arranged in the object light path may be corrected as necessary.

In the object light path, the radiation may be coupled into optical probe OSO, so that the radiation illuminates the surface to be measured of measured object O. The surface of the object may be imaged by optical probe OSO via one or more intermediate images on photodetector equipment in the form of an image converter or image sensor BS, for instance, a CCD camera. The image of measured object O on image sensor BS may be superposed with the reference wave of the second beam component. A high interference contrast occurs in the image of measured object O when the path difference in the reference light path and the measured light path is less than the coherence length. With regard to this, the measuring principle may be based on white-light interferometry (short-coherent interferometry), as is described in greater detail in the documents mentioned at the outset. The length of the reference light path may be varied over the entire measuring range for scanning in the depth direction of the surface to be measured, the length of the reference light path being detected for each measured point at which the greatest interference contrast appears. It may be possible by the intermediate images to image the surface of the measured object at a high lateral resolution over a range that is large compared to the diameter of the imaging optics. Optical probe OSO resembles an endoscope and a borescope, however, the illumination and the feedback of the radiation coming from the measured surface via the same optical device occurring via at least one intermediate image. Figure 1 illustrates schematically some lenses L as further imaging elements. The actual intermediate images may be created in optical probe OSO.

For applications, in which an exact compensation for the influence of the imaging lenses of optical probe OSO is required, the same optical probe OSR is also integrated in the

reference light path or reference arm between beam splitter ST1 and reference mirror RSP as in the object light path between beam splitter ST1 and measuring object O, as illustrated in Figure 2.

In a modified design according to Figure 3, the interferometric measuring device may also be realized as a device having common reference and measuring arms (common path device). The interferometric measuring device may be again illuminated by a short-coherent (broadband) radiation-producing unit. Beam splitter ST1 splits the light in two arms into first beam component T1 and second beam component T2, first beam component T1 falling on a first, fixed mirror SP1, and second beam component T2 falling on reflecting element RSP in the form of a reference mirror.

The optical path difference between the arms thus formed is greater than the coherence length of the radiation produced by radiation-producing unit SLD. Starting from the two mirrors SP1 and RSP, the reflected radiation is fed to optical probe OS via beam splitter ST1 and a further beam splitter ST2. The special quality of this design may be that there is a reference mirror RSP2 in optical probe OS itself.

A part of the radiation may be reflected by this reference mirror RSP2, while the other part of the radiation illuminates the surface to be measured. Reference mirror RSP2 may be mounted on flat face-plate or on a prism. By using a prism, the wave front of the radiation illuminating the object surface, i.e. of the object wave may be adapted to the geometry (e.g. inclination) of the surface to be measured. With the aid of optical probe OS, measured object O may be in turn imaged via one or more intermediate images on image sensor BS, and superposed by the reference wave. In order to obtain height information, reflecting element RSP may be made to traverse the measuring range, or changing the light path may be undertaken as described above. In the image of measured

object O great interference contrast appears when the path difference between fixed mirror SP1 and reflecting element RSP or of the light paths of the two arms is exactly the same as the optical path difference between reference mirror RSP2 and measured object O. In order to obtain the height profile, conventional methods for detecting the greatest interference contrast may be used in each image point (pixel). The benefit of this design may be that the object and reference waves pass through virtually the identical optics assembly, so that aberrations may be substantially compensated for. Moreover, this set-up may be more rugged and, therefore, less susceptible to mechanical shocks.

For even simpler handling of the measuring device, the radiation of beam splitter ST1 may also be transmitted to further beam splitter ST1, using fiber optics LF, as is illustrated in Figure 4.

A further alternative design is illustrated in Figure 5. As an alternative to the design having the common reference path and measuring light path as in Figures 3 and 4, a combined Mach-Zehnder-Michelson arrangement is provided. Again, a broadband radiation-producing unit SLD may be used, whose radiation may be coupled into a fiber optic element. First beam splitter ST1 splits the radiation into an object arm OA and a reference arm RA. In object arm OA, first beam component T1 may be coupled out of the corresponding light conducting fiber and coupled into optical probe OSO via further beam splitter ST2, so that the surface to be measured of measured object O may be illuminated. The object surface may be imaged by optical probe OSO via one or more intermediate images on image sensor BS. In reference arm RA light may be coupled out of the corresponding light-conducting fiber, may be then propagated, if necessary, through the same optical probe OSR as may be applied in object arm OA, and may be coupled in by a second fiber coupler R2 to a light-conducting fiber positioned there. The reference wave reaches further beam splitter ST2

via the light-conducting fiber. There it may be uncoupled and superposed with the object wave on image sensor BS via further beam splitter ST2. In both arms, the optical paths in the air, in optical probes OSO or OSR as well as in the light-conducting fibers have to be adjusted. Tuning of the path lengths in reference arm RA may be performed here, for example, by shifting second fiber coupler R2, so that the optical air path in the reference arm may be changed.

ABSTRACT

An interferometric measuring device for measuring the shape of rough surfaces of a measured object is provided. The device includes a radiation-producing unit emitting short-coherent radiation, a beam splitter for forming a first and a second beam component, of which the first may be directed via an object light path to the measured object, and the second may be directed via a reference light path to a reflecting reference plane. The device also includes a superposition element at which the radiation coming from the measured object and the reference plane may be brought to superposition, and an image converter, which receives the superposed radiation and sends corresponding signals to a device for evaluation, for the measurement to be taken, the optical path length of the object light path being changed relative to the optical path length of the reference light path. An exact measuring of object surfaces in narrow cavities, in three dimensions, having great accuracy, may be made possible by providing in the optical light path an optical probe having an optical arrangement for producing at least one optical intermediate image.

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INTERFEROMETRIC MEASURING DEVICE FOR MEASURING SHAPE

[Background Information

] **FIELD OF THE INVENTION**

The present invention relates to an interferometric measuring device for measuring the shape especially of rough surfaces of a measured object, having a radiation-producing unit emitting short-coherent radiation, a beam splitter for forming a first and a second beam component, of which the first is directed via an object light path to the measured object and the second is directed via a reference light path to a reflective reference plane, having a superposition element at which the radiation coming from the measured object and the reference plane are brought to superposition, and an image converter which receives the superposed radiation and sends corresponding signals to a device for evaluation, the optical path length of the object light path being changed relative to the optical path length of the reference light path.

BACKGROUND INFORMATION

Interferometric [Such an interferometric] measuring device**s** [is] **are** known from German **published patent document No.** [DE] 197 21 842 [C2]. In the case of this [known] **conventional** measuring device, a radiation-producing unit, such as a light-emitting diode or a superluminescent diode, emits a short-coherent radiation, which is split via a beam splitter into a first beam component guided over an object light path, and a second beam component guided over a reference light path. The reference light path is periodically changed, using two deflector elements and a stationary diffraction grating positioned behind it, by activating the deflector elements, so

as to scan the object surface in the depth direction. If the object light path and the reference light path coincide, a maximum interference contrast results, which is detected using an evaluation device post-connected to the photodetector device.

An interferometric measuring device representative of the measuring principle (white-light interferometry or short-coherent interferometry) is also specified in German **published patent document No.** [DE] 41 08 944 [A1]. Here, however, a moved mirror is used to change the light path in the reference ray path. In this method, the surface of the object is imaged on the photodetector device, using an optical system, it being difficult, however, to conduct measurements in cavities.

Additional such interferometric measuring devices and interferometric measuring methods based on white-light interferometry are described by P. de Groot, L. Deck, "Surface Profiling by Analysis of white-Light Interferograms in the Spatial Frequency Domain" J. Mod. Opt., Vol. 42, No. 2, 389-401, 1995 and No. T. Maack, G. Notni, W. Schreiber, W.-D. Prenzel, "Endoskopisches 3-D-Formmesssystem",(Endoscopic 3-D Shape Measuring System) in Jahrbuch für Optik und Feinmechanik, Ed. W.-D. Prenzel, Verlag (publisher) Schiele und Schoen, Berlin, 231-240, 1998 [verwiesen] (submitted).

In the case of the interferometric measuring devices and measuring methods named, one difficulty is making measurements in deep cavities or narrow ducts. One suggestion for a measuring device in which measurements [can] **may** be performed even in cavities, using white-light interferometry, is [shown] **described** in German **published patent document No.** [DE] 197 21 843 [C1]. It is [proposed] **described** there to split a first beam component further into a reference beam component and at least one measuring beam component, an additional beam

splitter and the reference mirror being positioned in a common measuring probe. To be sure, such a measuring probe [can] **may** be introduced into cavities, however, using this device, in each measurement, only a small, dot-like location in the surface [can] **may** be scanned. In order to take the measure of more locations on the surface in the depth direction, relative motion between measured object and measuring probe is required, an exact lateral coordination, however, being costly and difficult.

SUMMARY

The object of the present invention is to make available an interferometric measuring device, of the kind mentioned at the outset, which especially makes possible simplified measurements in deep cavities with great accuracy.

[This object is achieved by the features of Claim 1.] According to [this] **the present invention** it is provided that an optical probe in the object light path, having an optical device for generating at least one optical intermediate image, be provided.

Similarly to an endoscope or a borescope, in using the optical device, because of the intermediate images, it becomes possible to image the observed surface, besides using high longitudinal resolution, also at high lateral resolution over a path which [is] **may be** long compared to the diameter of the imaging optics. For example, the optical probe [can] **may** be introduced into the bores of valve seats or into vessels of organisms for the purpose of medical measurements. In contrast to the usual endoscope, quantitative depth information [is] **may be** now obtained. In this connection, an [advantageous] **example** embodiment [is] **may be** one in which the at least one intermediate image is generated in the object light path. For this, the same optical device [is] **may be** used for illuminating the measured location on the measured object as

for transmitting the radiation coming from the measured object to the photodetector device, if it is provided that both the radiation going to the measured object and the radiation coming back from it pass through the optical probe.

The optical image on the photodetector device [can] **may** be improved by providing, in the reference light path, an equal, further optical probe or at least a glass device for compensating for a glass proportion present in the optical probe with regard to the elements for the intermediate image(s).

A favorable construction, as far as handling is concerned, [is] **may be** one in which the optical motion difference between the first and the second arm is greater than the coherence length of the radiation; the radiation coming from the first mirror and the reflecting element [are] **may be** guided through a common optical probe (common path) using a further radiation portion; in the optical probe, a reference mirror is arranged at such a distance from the measured object that the motion difference between the first mirror and the reflecting element is canceled, and one part of the radiation incident on the reference mirror is reflected to the photodetector device and one part is allowed to pass through to the measured object and is reflected from there to the photodetector device. A further benefit of this design [is] **may be** that the object and reference waves pass through virtually the identical optics assembly, so that aberrations [are] **may be** substantially compensated for. Moreover, this set-up [is] **may be** more resistant to mechanical shocks. In this connection, two **example** embodiment possibilities [are] **may be,** for the reference mirror**,** [to be] provided on a flat face-plate or on a prism.

In this connection, handling [can] **may** further be simplified by arranging a fiber optic element between the beam splitter

and the further beam splitter.

In this design too, splitting essentially into a probe part and a part having a modulation arrangement [is] **may be** realized, handling being also favored.

The present invention is [elucidated] **described** in the following on the basis of [exemplary] **example** embodiments, with reference to the drawings. [The figures show:]

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 [a first exemplary] **illustrates an example** embodiment of an interferometric measuring device having an optical probe in a measured light path.

Figure 2 [a second exemplary] **illustrates an example** embodiment in which an optical probe is provided both in the measured light path and in the reference light path.

Figure 3 **illustrates an embodiment** [a design] of the interferometric measuring device having a common reference and measured light path.

Figure 4 [a further exemplary] **illustrates an example** embodiment in which, compared to Figure 3, fiber optics are provided between the first and a further beam splitter.

Figure 5 [a further design] **illustrates a further** example **embodiment** of the interferometric measuring device.

DETAILED DESCRIPTION

Figure 1 [shows] **illustrates** an interferometric measuring device having a radiation-producing unit SLD emitting short-coherent radiation, as, for example a light-emitting diode or a superluminescent diode, whose radiation [is] **may be**

split by a beam splitter ST1 into a first beam component T1 of a measured light path and a second beam component T2 of a reference light path. The design [is] **may be** like that of a Michelson interferometer. In the reference light path, the second beam component [is] **may be** reflected by a reference plane in the form of a reference mirror RSP, the reference light path being periodically changed by moving the reference mirror RSP or by acoustooptical deflectors, as described in German **published patent document No.** [DE] 197 21 842 [C2], mentioned at the outset. If the change of the light path [is] **may be** performed using two acoustooptical deflectors, a mechanically moved reflecting element becomes unnecessary, but instead, a fixed element, [particularly] **e.g.,** a diffraction grating, [can] **may** be used. By using a glass block G, the dispersion of an optical probe OSO arranged in the object light path [can] **may** be corrected as necessary.

In the object light path, the radiation [is] **may be** coupled into optical probe OSO, so that the radiation illuminates the surface to be measured of measured object O. The surface of the object [is] **may be** imaged by optical probe OSO via one or more intermediate images on photodetector equipment in the form of an image converter or image sensor BS, for instance, a CCD camera. The image of measured object O on image sensor BS [is] **may be** superposed with the reference wave of the second beam component. A high interference contrast occurs in the image of measured object O when the path difference in the reference light path and the measured light path is less than the coherence length. With regard to this, the measuring principle [is] **may be** based on white-light interferometry (short-coherent interferometry), as is described in greater detail in the documents mentioned at the outset. The length of the reference light path [is] **may be** varied over the entire measuring range for scanning in the depth direction of the surface to be measured, the length of the reference light path

being detected for each measured point at which the greatest interference contrast appears. It [is made] **may be** possible by the intermediate images to image the surface of the measured object at a high lateral resolution over a range that is large compared to the diameter of the imaging optics. Optical probe OSO resembles an endoscope and a borescope, however, the illumination and the feedback of the radiation coming from the measured surface via the same optical device occurring via at least one intermediate image. Figure 1 [shows] **illustrates** schematically some lenses L as further imaging elements. The actual intermediate images [are] **may be** created in optical probe OSO.

For applications, in which an exact compensation for the influence of the imaging lenses of optical probe OSO is required, the same optical probe OSR is also integrated in the reference light path or reference arm between beam splitter ST1 and reference mirror RSP as in the object light path between beam splitter ST1 and measuring object O, as [shown] **illustrated** in Figure 2.

In a modified design according to Figure 3, the interferometric measuring device may also be realized as a device having common reference and measuring arms (common path device). The interferometric measuring device [is] **may be** again illuminated by a short-coherent (broadband) radiation-producing unit. Beam splitter ST1 splits the light in two arms into first beam component T1 and second beam component T2, first beam component T1 falling on a first, fixed mirror SP1, and second beam component T2 falling on reflecting element RSP in the form of a reference mirror.

The optical path difference between the arms thus formed is greater than the coherence length of the radiation produced by radiation-producing unit SLD. Starting from the two mirrors SP1 and RSP, the reflected radiation is fed to optical probe

OS via beam splitter ST1 and a further beam splitter ST2. The special quality of this design [is] **may be** that there is a reference mirror RSP2 in optical probe OS itself.

A part of the radiation [is] **may be** reflected by this reference mirror RSP2, while the other part of the radiation illuminates the surface to be measured. Reference mirror RSP2 may be mounted on flat face-plate or on a prism. By using a prism, the wave front of the radiation illuminating the object surface, i.e. of the object wave [can] **may** be adapted to the geometry (e.g. inclination) of the surface to be measured. With the aid of optical probe OS, measured object O [is] **may be** in turn imaged via one or more intermediate images on image sensor BS, and superposed by the reference wave. In order to obtain height information, reflecting element RSP [is] **may be** made to traverse the measuring range, or changing the light path [is] **may be** undertaken as described above. In the image of measured object O great interference contrast appears when the path difference between fixed mirror SP1 and reflecting element RSP or of the light paths of the two arms is exactly the same as the optical path difference between reference mirror RSP2 and measured object O. In order to obtain the height profile, [known] **conventional** methods for detecting the greatest interference contrast [are] **may be** used in each image point (pixel). The benefit of this design [is] **may be** that the object and reference waves pass through virtually the identical optics assembly, so that aberrations [are] **may be** substantially compensated for. Moreover, this set-up [is] **may be** more rugged and, therefore, less susceptible to mechanical shocks.

For even simpler handling of the measuring device, the radiation of beam splitter ST1 [can] **may** also be transmitted to further beam splitter ST1, using fiber optics LF, as is [shown] **illustrated** in Figure 4.

A further alternative design is [shown] **illustrated** in Figure 5. As an alternative to the design having the common reference path and measuring light path as in Figures 3 and 4, a combined Mach-Zehnder-Michelson arrangement is provided. Again, a broadband radiation-producing unit SLD [is] **may be** used, whose radiation [is] **may be** coupled into a fiber optic element. First beam splitter ST1 splits the radiation into an object arm OA and a reference arm RA. In object arm OA, first beam component T1 [is] **may be** coupled out of the corresponding light conducting fiber and coupled into optical probe OSO via further beam splitter ST2, so that the surface to be measured of measured object O [is] **may be** illuminated. The object surface [is] **may be** imaged by optical probe OSO via one or more intermediate images on image sensor BS. In reference arm RA light [is] **may be** coupled out of the corresponding light-conducting fiber, [is] **may be** then propagated, if necessary, through the same optical probe OSR as [is] **may be** applied in object arm OA, and [is] **may be** coupled in by a second fiber coupler R2 to a light-conducting fiber positioned there. The reference wave reaches further beam splitter ST2 via the light-conducting fiber. There it [is] **may be** uncoupled and superposed with the object wave on image sensor BS via further beam splitter ST2. In both arms, the optical paths in the air, in optical probes OSO or OSR as well as in the light-conducting fibers have to be adjusted. Tuning of the path lengths in reference arm RA [is] **may be** performed here, for example, by shifting second fiber coupler R2, so that the optical air path in the reference arm [is] **may be** changed.

[Abstract

] **ABSTRACT**

An [The present invention relates to a] interferometric measuring device for measuring the shape [especially] of rough surfaces of a measured object **is provided.** [(O), having] **The device includes** a radiation-producing unit [(SLD)] emitting short-coherent radiation, a beam splitter [(ST1)] for forming a first and a second beam component [(T1, T2)], of which the first [is] **may be** directed via an object light path to the measured object [(O)], and the second [is] **may be** directed via a reference light path to a reflecting reference plane**.** [(RSP), having] **The device also includes** a superposition element at which the radiation coming from the measured object [(O)] and the reference plane [(RSP) are] **may be** brought to superposition, and an image converter [(BS)], which receives the superposed radiation and sends corresponding signals to a device for evaluation, for the measurement to be taken, the optical path length of the object light path being changed relative to the optical path length of the reference light path. An exact measuring of object surfaces in narrow cavities, in three dimensions, having great accuracy, [is] **may be** made possible by providing in the optical light path an optical probe [(OS, OSO)] having an optical arrangement for producing at least one optical intermediate image.

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INTERFEROMETRIC MEASURING DEVICE FOR MEASURING SHAPE

Background Information

The present invention relates to an interferometric measuring device for measuring the shape especially of rough surfaces of a measured object, having a radiation-producing unit emitting short-coherent radiation, a beam splitter for forming a first and a second beam component, of which the first is directed via an object light path to the measured object and the second is directed via a reference light path to a reflective reference plane, having a superposition element at which the radiation coming from the measured object and the reference plane are brought to superposition, and an image converter which receives the superposed radiation and sends corresponding signals to a device for evaluation, the optical path length of the object light path being changed relative to the optical path length of the reference light path.

Such an interferometric measuring device is known from German DE 197 21 842 C2. In the case of this known measuring device, a radiation-producing unit, such as a light-emitting diode or a superluminescent diode, emits a short-coherent radiation, which is split via a beam splitter into a first beam component guided over an object light path, and a second beam component guided over a reference light path. The reference light path is periodically changed, using two deflector elements and a stationary diffraction grating positioned behind it, by activating the deflector elements, so as to scan the object surface in the depth direction. If the object light path and the reference light path coincide, a maximum interference

contrast results, which is detected using an evaluation device post-connected to the photodetector device.

An interferometric measuring device representative of the measuring principle (white-light interferometry or short-coherent interferometry) is also specified in German DE 41 08 944 A1. Here, however, a moved mirror is used to change the light path in the reference ray path. In this method, the surface of the object is imaged on the photodetector device, using an optical system, it being difficult, however, to conduct measurements in cavities.

Additional such interferometric measuring devices and interferometric measuring methods based on white-light interferometry are described by P. de Groot, L. Deck, "Surface Profiling by Analysis of white-Light Interferograms in the Spatial Frequency Domain" J. Mod. Opt., Vol. 42, No. 2, 389-401, 1995 and No. T. Maack, G. Notni, W. Schreiber, W.-D. Prenzel, "Endoskopisches 3-D-Formmesssystem",(Endoscopic 3-D Shape Measuring System) in Jahrbuch für Optik und Feinmechanik, Ed. W.-D. Prenzel, Verlag (publisher) Schiele und Schoen, Berlin, 231-240, 1998 verwiesen (submitted).

In the case of the interferometric measuring devices and measuring methods named, one difficulty is making measurements in deep cavities or narrow ducts. One suggestion for a measuring device in which measurements can be performed even in cavities, using white-light interferometry, is shown in German DE 197 21 843 C1. It is proposed there to split a first beam component further into a reference beam component and at least one measuring beam component, an additional beam splitter and the reference mirror being positioned in a common measuring probe. To be sure, such a measuring probe can be introduced into cavities, however, using this device, in each measurement, only a small, dot-like location in the surface can be scanned. In order to take the measure of more locations on the surface in the depth direction, relative motion between

measured object and measuring probe is required, an exact lateral coordination, however, being costly and difficult.

The object of the present invention is to make available an interferometric measuring device, of the kind mentioned at the outset, which especially makes possible simplified measurements in deep cavities with great accuracy.

This object is achieved by the features of Claim 1. According to this it is provided that an optical probe in the object light path, having an optical device for generating at least one optical intermediate image, be provided.

Similarly to an endoscope or a borescope, in using the optical device, because of the intermediate images, it becomes possible to image the observed surface, besides using high longitudinal resolution, also at high lateral resolution over a path which is long compared to the diameter of the imaging optics. For example, the optical probe can be introduced into the bores of valve seats or into vessels of organisms for the purpose of medical measurements. In contrast to the usual endoscope, quantitative depth information is now obtained. In this connection, an advantageous embodiment is one in which the at least one intermediate image is generated in the object light path. For this, the same optical device is used for illuminating the measured location on the measured object as for transmitting the radiation coming from the measured object to the photodetector device, if it is provided that both the radiation going to the measured object and the radiation coming back from it pass through the optical probe.

The optical image on the photodetector device can be improved by providing, in the reference light path, an equal, further optical probe or at least a glass device for compensating for a glass proportion present in the optical probe with regard to the elements for the intermediate image(s).

A favorable construction, as far as handling is concerned, is one in which the optical motion difference between the first and the second arm is greater than the coherence length of the radiation; the radiation coming from the first mirror and the reflecting element are guided through a common optical probe (common path) using a further radiation portion; in the optical probe, a reference mirror is arranged at such a distance from the measured object that the motion difference between the first mirror and the reflecting element is canceled, and one part of the radiation incident on the reference mirror is reflected to the photodetector device and one part is allowed to pass through to the measured object and is reflected from there to the photodetector device. A further benefit of this design is that the object and reference waves pass through virtually the identical optics assembly, so that aberrations are substantially compensated for. Moreover, this set-up is more resistant to mechanical shocks. In this connection, two embodiment possibilities are for the reference mirror to be provided on a flat face-plate or on a prism.

In this connection, handling can further be simplified by arranging a fiber optic element between the beam splitter and the further beam splitter.

In this design too, splitting essentially into a probe part and a part having a modulation arrangement is realized, handling being also favored.

The present invention is elucidated in the following on the basis of exemplary embodiments, with reference to the drawings. The figures show:

Figure 1 a first exemplary embodiment of an interferometric measuring device having an optical probe in a measured light path.

Figure 2 a second exemplary embodiment in which an optical

probe is provided both in the measured light path and in the reference light path.

Figure 3 a design of the interferometric measuring device having a common reference and measured light path.

Figure 4 a further exemplary embodiment in which, compared to Figure 3, fiber optics are provided between the first and a further beam splitter.

Figure 5 a further design example of the interferometric measuring device.

Figure 1 shows an interferometric measuring device having a radiation-producing unit SLD emitting short-coherent radiation, as, for example a light-emitting diode or a superluminescent diode, whose radiation is split by a beam splitter ST1 into a first beam component T1 of a measured light path and a second beam component T2 of a reference light path. The design is like that of a Michelson interferometer. In the reference light path, the second beam component is reflected by a reference plane in the form of a reference mirror RSP, the reference light path being periodically changed by moving the reference mirror RSP or by acoustooptical deflectors, as described in German DE 197 21 842 C2, mentioned at the outset. If the change of the light path is performed using two acoustooptical deflectors, a mechanically moved reflecting element becomes unnecessary, but instead, a fixed element, particularly a diffraction grating, can be used. By using a glass block G, the dispersion of an optical probe OSO arranged in the object light path can be corrected as necessary.

In the object light path, the radiation is coupled into optical probe OSO, so that the radiation illuminates the surface to be measured of measured object O. The surface of the object is imaged by optical probe OSO via one or more

intermediate images on photodetector equipment in the form of an image converter or image sensor BS, for instance, a CCD camera. The image of measured object O on image sensor BS is superposed with the reference wave of the second beam component. A high interference contrast occurs in the image of measured object O when the path difference in the reference light path and the measured light path is less than the coherence length. With regard to this, the measuring principle is based on white-light interferometry (short-coherent interferometry), as is described in greater detail in the documents mentioned at the outset. The length of the reference light path is varied over the entire measuring range for scanning in the depth direction of the surface to be measured, the length of the reference light path being detected for each measured point at which the greatest interference contrast appears. It is made possible by the intermediate images to image the surface of the measured object at a high lateral resolution over a range that is large compared to the diameter of the imaging optics. Optical probe OSO resembles an endoscope and a borescope, however, the illumination and the feedback of the radiation coming from the measured surface via the same optical device occurring via at least one intermediate image. Figure 1 shows schematically some lenses L as further imaging elements. The actual intermediate images are created in optical probe OSO.

For applications, in which an exact compensation for the influence of the imaging lenses of optical probe OSO is required, the same optical probe OSR is also integrated in the reference light path or reference arm between beam splitter ST1 and reference mirror RSP as in the object light path between beam splitter ST1 and measuring object O, as shown in Figure 2.

In a modified design according to Figure 3, the interferometric measuring device may also be realized as a device having common reference and measuring arms (common path

device). The interferometric measuring device is again illuminated by a short-coherent (broadband) radiation-producing unit. Beam splitter ST1 splits the light in two arms into first beam component T1 and second beam component T2, first beam component T1 falling on a first, fixed mirror SP1, and second beam component T2 falling on reflecting element RSP in the form of a reference mirror.

The optical path difference between the arms thus formed is greater than the coherence length of the radiation produced by radiation-producing unit SLD. Starting from the two mirrors SP1 and RSP, the reflected radiation is fed to optical probe OS via beam splitter ST1 and a further beam splitter ST2. The special quality of this design is that there is a reference mirror RSP2 in optical probe OS itself.

A part of the radiation is reflected by this reference mirror RSP2, while the other part of the radiation illuminates the surface to be measured. Reference mirror RSP2 may be mounted on flat face-plate or on a prism. By using a prism, the wave front of the radiation illuminating the object surface, i.e. of the object wave can be adapted to the geometry (e.g. inclination) of the surface to be measured. With the aid of optical probe OS, measured object O is in turn imaged via one or more intermediate images on image sensor BS, and superposed by the reference wave. In order to obtain height information, reflecting element RSP is made to traverse the measuring range, or changing the light path is undertaken as described above. In the image of measured object O great interference contrast appears when the path difference between fixed mirror SP1 and reflecting element RSP or of the light paths of the two arms is exactly the same as the optical path difference between reference mirror RSP2 and measured object O. In order to obtain the height profile, known methods for detecting the greatest interference contrast are used in each image point (pixel). The benefit of this design is that the object and reference waves pass through virtually the identical optics

assembly, so that aberrations are substantially compensated for. Moreover, this set-up is more rugged and, therefore, less susceptible to mechanical shocks.

For even simpler handling of the measuring device, the radiation of beam splitter ST1 can also be transmitted to further beam splitter ST1, using fiber optics LF, as is shown in Figure 4.

A further alternative design is shown in Figure 5. As an alternative to the design having the common reference path and measuring light path as in Figures 3 and 4, a combined Mach-Zehnder-Michelson arrangement is provided. Again, a broadband radiation-producing unit SLD is used, whose radiation is coupled into a fiber optic element. First beam splitter ST1 splits the radiation into an object arm OA and a reference arm RA. In object arm OA, first beam component T1 is coupled out of the corresponding light conducting fiber and coupled into optical probe OSO via further beam splitter ST2, so that the surface to be measured of measured object O is illuminated. The object surface is imaged by optical probe OSO via one or more intermediate images on image sensor BS. In reference arm RA light is coupled out of the corresponding light-conducting fiber, is then propagated, if necessary, through the same optical probe OSR as is applied in object arm OA, and is coupled in by a second fiber coupler R2 to a light-conducting fiber positioned there. The reference wave reaches further beam splitter ST2 via the light-conducting fiber. There it is uncoupled and superposed with the object wave on image sensor BS via further beam splitter ST2. In both arms, the optical paths in the air, in optical probes OSO or OSR as well as in the light-conducting fibers have to be adjusted. Tuning of the path lengths in reference arm RA is performed here, for example, by shifting second fiber coupler R2, so that the optical air path in the reference arm is changed.

What is claimed is:

1. An interferometric measuring device for measuring shape, particularly rough surfaces of a measured object (O) having a radiation-producing unit (SLD) emitting short-coherent radiation, a beam splitter (ST1) for forming a first and a second beam component (T1, T2) of which the first is directed via an object light path to the measured object (O) and the second is directed via a reference light path to a reflecting reference plane (RSP), having a superposition element at which the radiation coming from the measured object (O) and the reference plane (RSP) are brought to superposition, and an image converter (BS), which receives the superposed radiation and sends corresponding signals to a device for evaluation, for the measurement, the optical path length of the object light path being changed relative to the optical path length of the reference light path, wherein an optical probe (OS, OSO) having an optical device for generating at least one optical intermediate image is provided in the object light path.

2. The measuring device as recited in Claim 1, wherein the at least one intermediate image is generated in the object light path.

3. The measuring device as recited in Claim 1 or 2, wherein both the radiation leading to the measured object (O) and the radiation returning from it pass through optical probe (OS, OSO).

4. The measuring device as recited in one of the preceding claims, wherein in the reference light path, an equal, further optical probe (OSR) or at least a glass device for compensating for a glass proportion present in the optical probe (OSO) with regard to the elements for the

intermediate image(s).

5. The measuring device as recited in one of the preceding claims,
wherein the first beam component (T1) formed by the beam splitter (ST1) is first directed via a first arm to a fixed first mirror (SP1), while the second beam component (T2) is directed via a second arm to the reflecting element (RSP); the optical path difference between the first and the second arm is greater than the coherence length of the radiation; the radiation coming from the first mirror (SP1) and the reflecting element (RSP) are guided through a common optical probe (OSO) using a further beam splitter (ST2); in the optical probe (OSO), a reference mirror (RSP2) is arranged at such a distance from the measured object that the path difference between the first mirror (SP1) and the reflecting element (RSP) is canceled, and one part of the radiation incident on the reference mirror (RSP2) is reflected to the photodetector device (BS) and one part is allowed to pass through to the measured object (O) and is reflected from there to the photodetector device (BS).

6. The measuring device as recited in Claim 5,
wherein the reference mirror (RSP2) is provided on a flat face-plate or a prism.

7. The measuring device as recited in Claim 5 or 6,
wherein a fiber optic element (LF) is positioned between the beam splitter (ST1) and the further beam splitter (ST2).

8. The measuring device as recited in one of Claims 1 through 4,
wherein the radiation emitted by the radiation-producing unit (SLD) is coupled into a fiber optic element and is subsequently split by the beam splitter (ST1) into the

first and the second beam component (T1, T2); the first beam component (T1) is coupled out of the fiberoptics in one object arm (OA) and coupled into optical probe (OSO) via a further beam splitter (ST2), and is guided to the measured object (O), from which the radiation is guided via the optical arrangement (L; L1 - L5; L6) to photodetector device (BS); the second beam component (T2) in one reference arm (RA) is coupled out of the fiber optics of the reference arm (RA), passes through the further optical probe (OSR), is guided via further fiber optics to the further beam splitter (ST2), and from there to the image converter (BS) for superposing by the radiation coming from the measured object (O).

Abstract

The present invention relates to a interferometric measuring device for measuring the shape especially of rough surfaces of a measured object (O), having a radiation-producing unit (SLD) emitting short-coherent radiation, a beam splitter (ST1) for forming a first and a second beam component (T1, T2), of which the first is directed via an object light path to the measured object (O), and the second is directed via a reference light path to a reflecting reference plane (RSP), having a superposition element at which the radiation coming from the measured object (O) and the reference plane (RSP) are brought to superposition, and an image converter (BS), which receives the superposed radiation and sends corresponding signals to a device for evaluation, for the measurement to be taken, the optical path length of the object light path being changed relative to the optical path length of the reference light path. An exact measuring of object surfaces in narrow cavities, in three dimensions, having great accuracy, is made possible by providing in the optical light path an optical probe (OS, OSO) having an optical arrangement for producing at least one optical intermediate image.

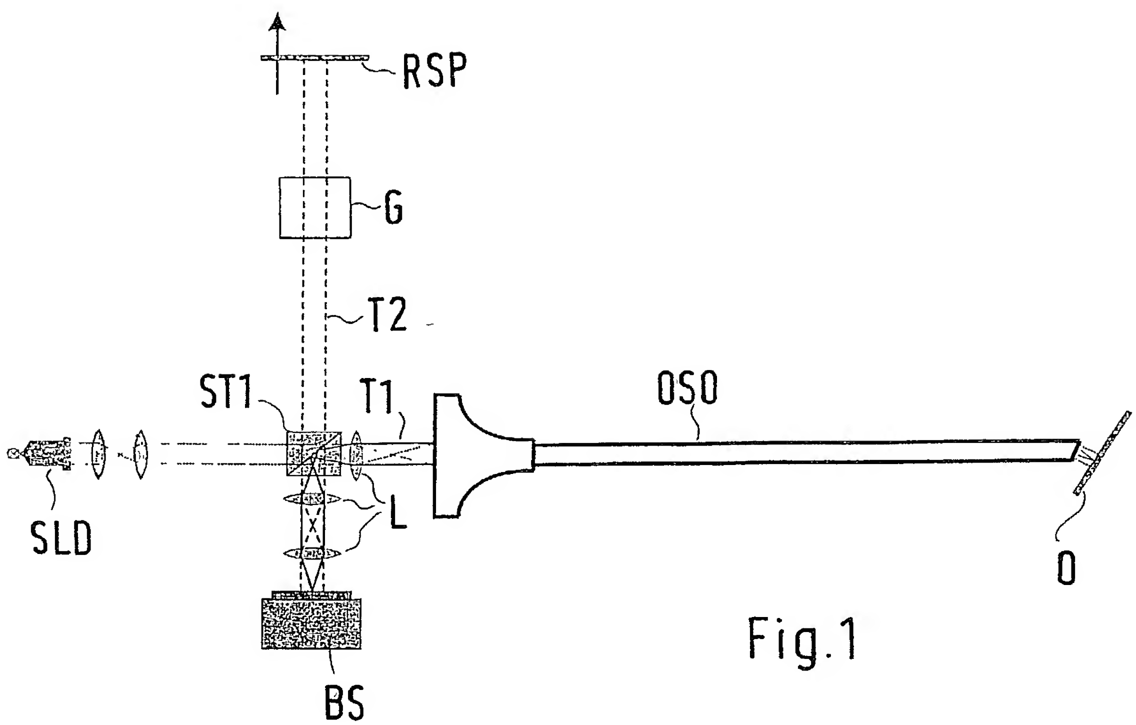

Fig.1

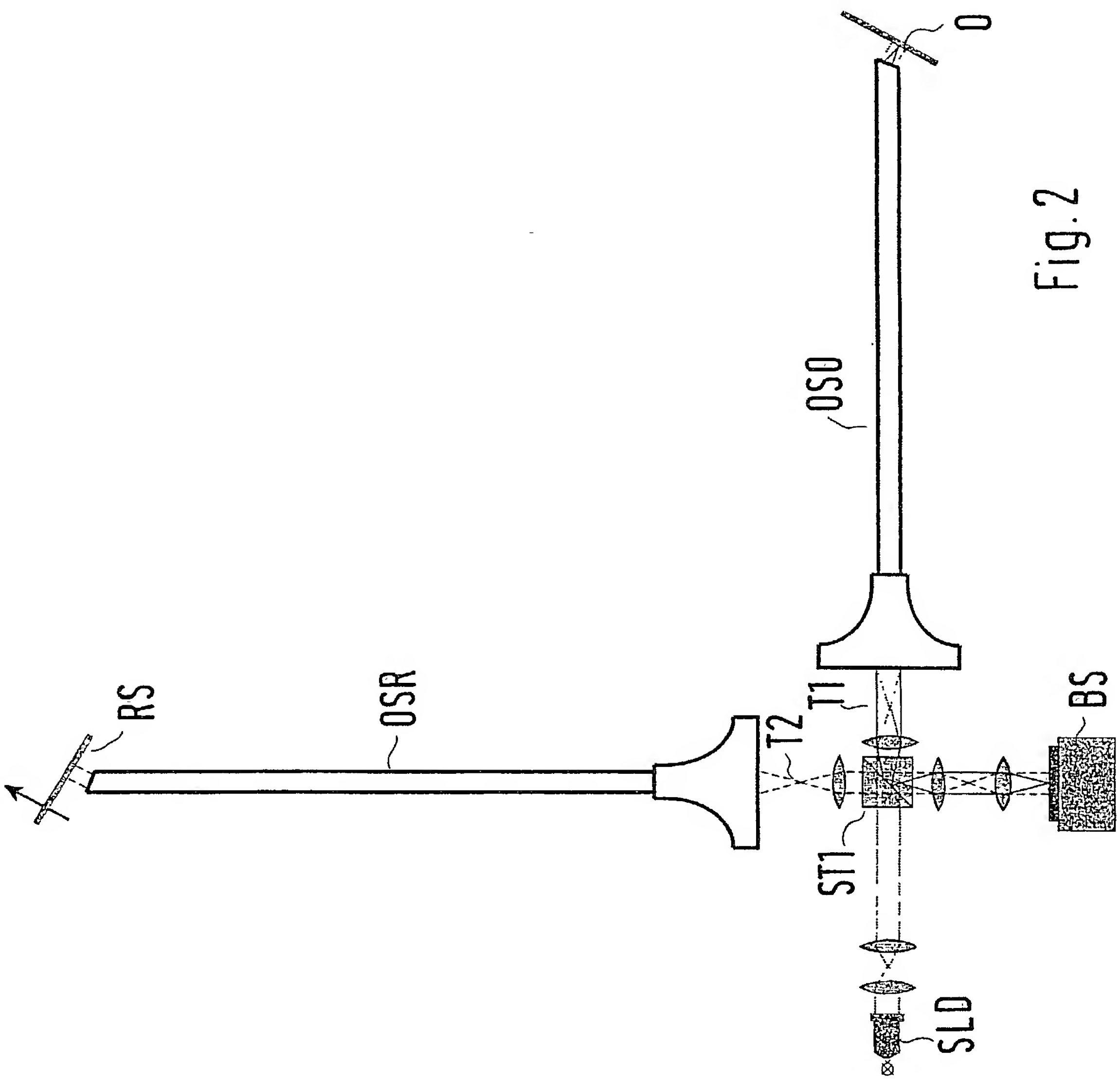

Fig.2

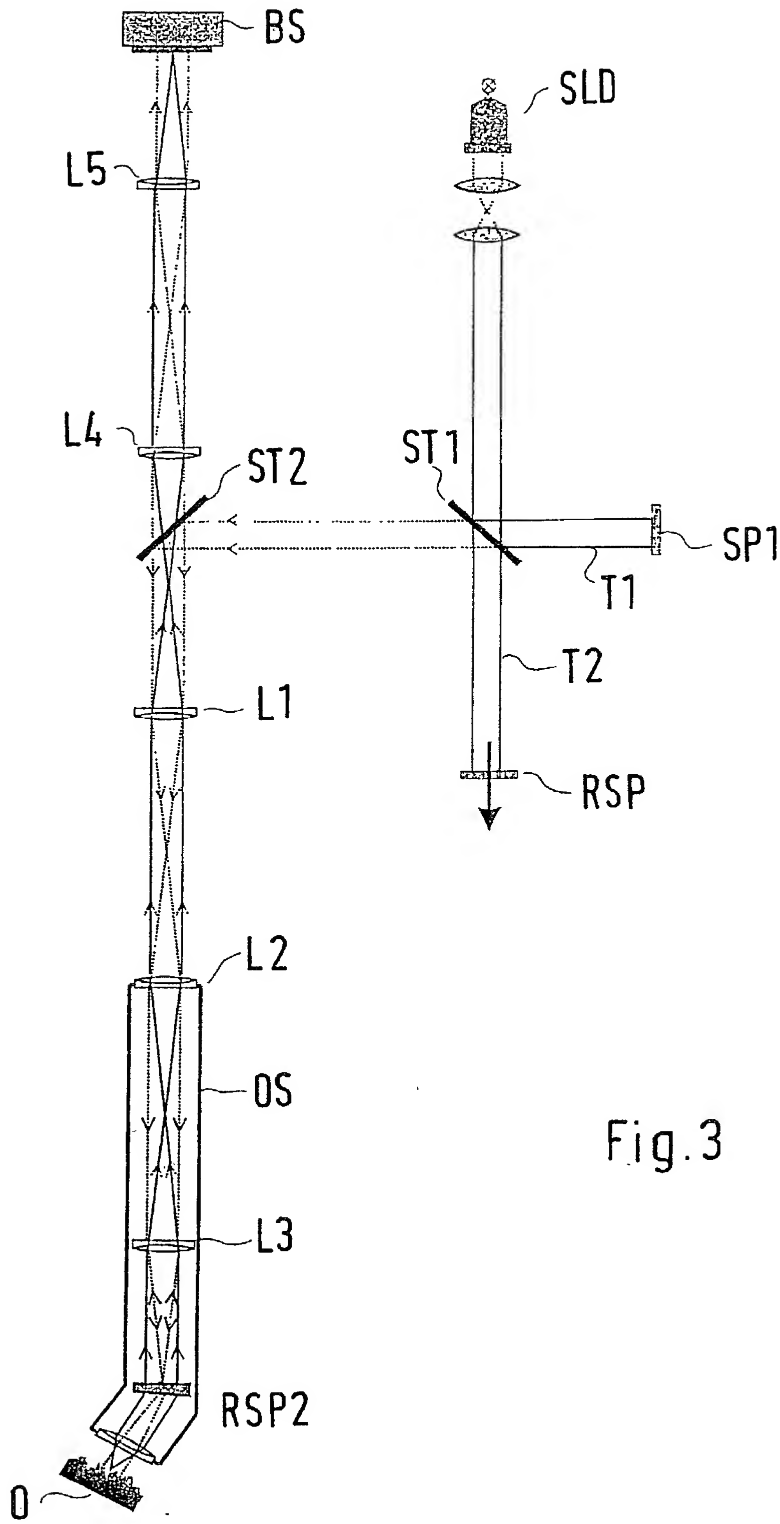

Fig.3

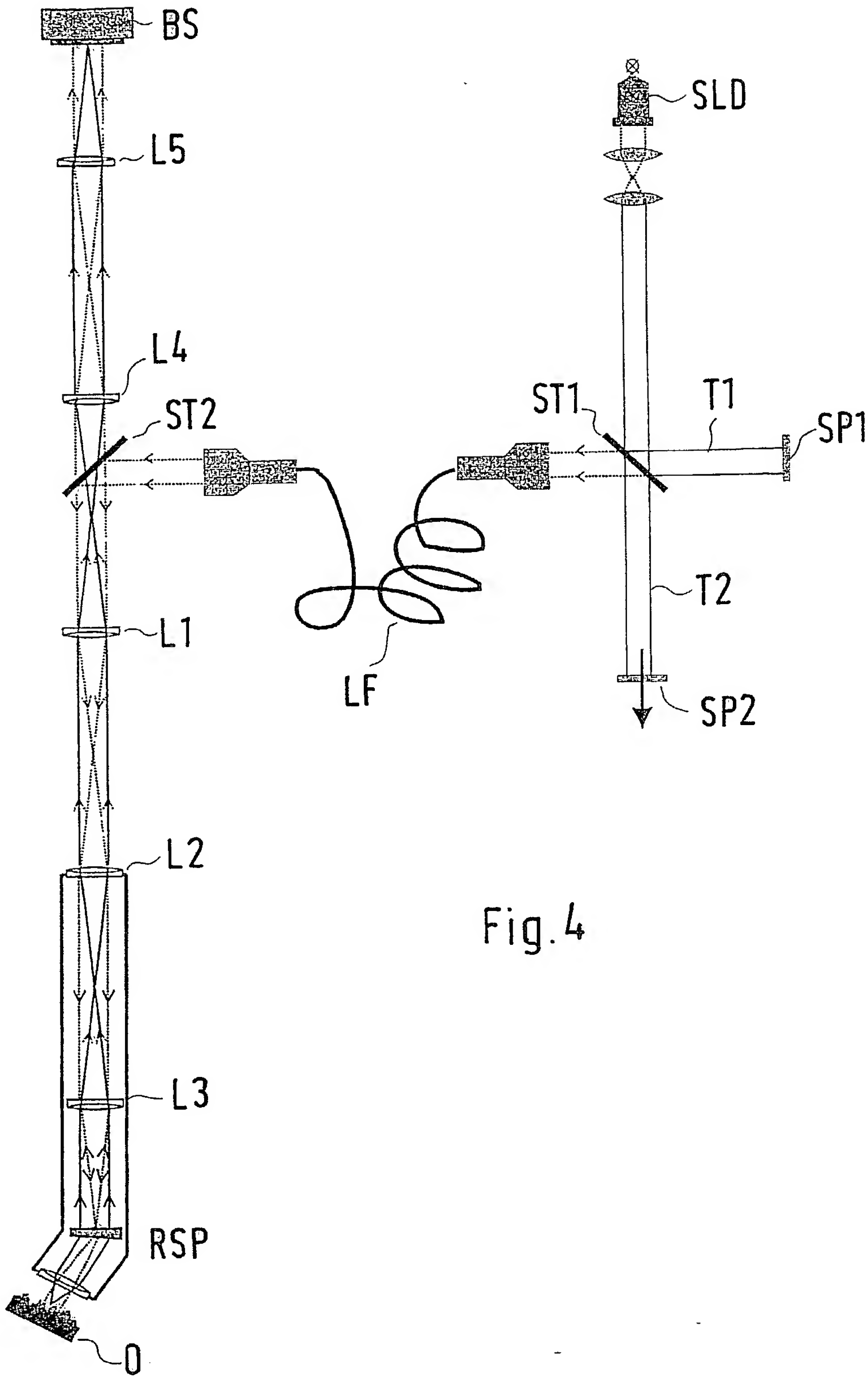

Fig. 4

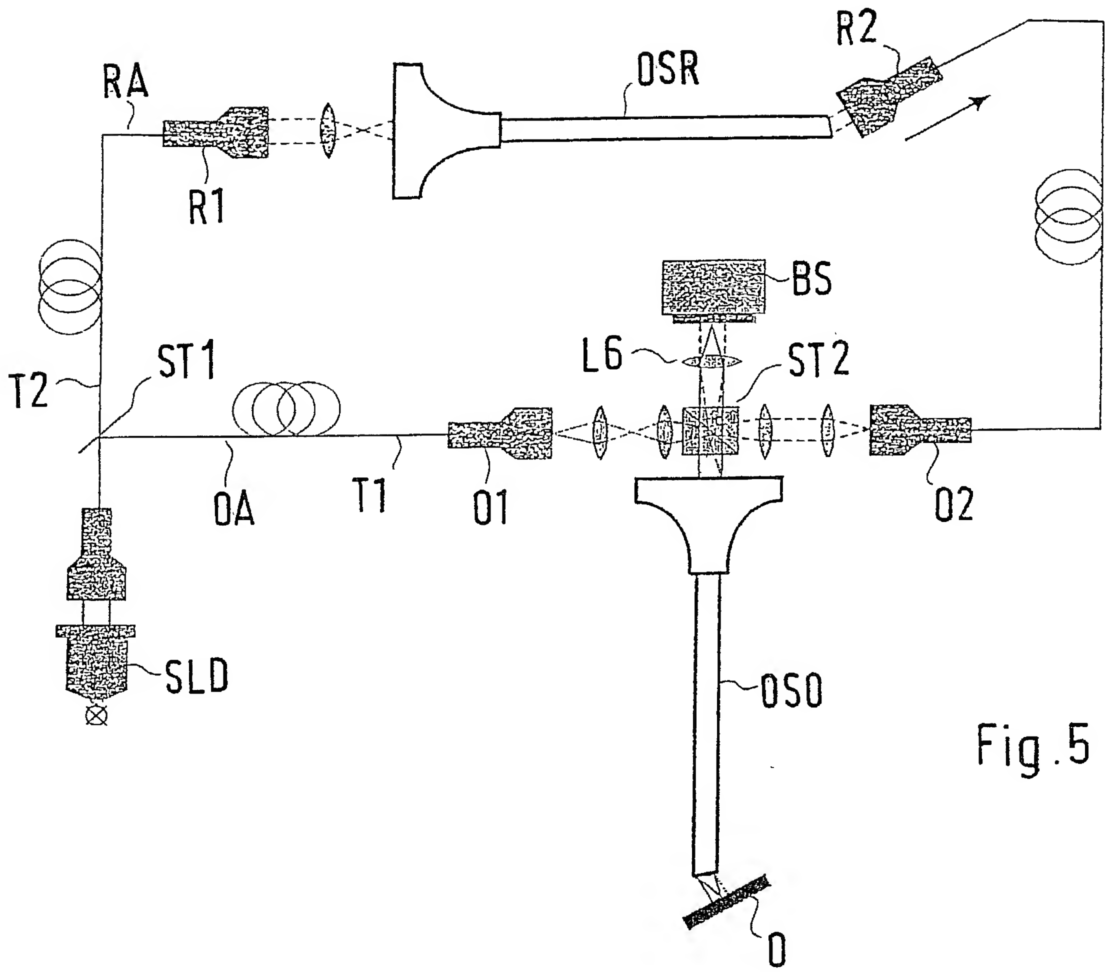

Fig. 5

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[10191/2287]

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **INTERFEROMETRIC MEASURING DEVICE FOR MEASURING SHAPE**, the specification of which was filed as International Application No. PCT/DE00/03547 on October 9, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

Number	Country Filed	Day/Month/Year	Priority Claimed Under 35 USC 119
199 48 813.4	Fed. Rep. of Germany	09 October 1999	Yes

EV 003690123

And I hereby appoint Richard L. Mayer (Reg. No. 22,490) and Gerard A. Messina (Reg. No. 35,952) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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Please direct all telephone calls to Richard L. Mayer at (212) 425-7200.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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